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SPACE LABORATORIES

USSR

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USSR

S. Matveyev

Radio
[Radio]
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Russian, per

"Soviet artificial satellites are sending not only radio signals and solar reflections to the earth. They are announcing to all people the summits to which the world of communism, freed from the path of capitalism, has attained."

(N. S. Khrushchev)

Four October 1959 became an historic landmark in the development of science. On that day the first artificial satellite of the earth was sent into space.

In speaking about the significance of this scientific achievement the President of the Academy of Sciences USSR, Academician A. N. Nesmeyanov, said:

"....On this day our fatherland raised a flag on a new era in the history of mankind -- the era on conquering space. This event stands in the ranks of such turning points in the ascent of mankind, as the discovery of fire, the invention of steam engines, the discovery of the electrical current and its action on a magnet which was the beginning of all electronics, the flight of the first airplane, and freeing energy from the atomic nucleus."

On 2 January 1959, the first Soviet space rocket reached the second cosmic speed, and having overcome the earth's pull, became an artificial satellite of the sun.

On 14 September 1959, the second Soviet space rocket reached the surface of the moon, and, finally, on 4 October 1959 on the second anniversary of the first artificial satellite of the earth, a third space rocket was put into orbit around the moon and earth. Such were the first steps into space.

Shooting ISZ [artificial earth satellites] and space rockets demanded that a number of very complicated problems be solved.

It was necessary to build an engine with tremendous power but weighing relatively little. In turn, this required the use of specially calorific fuel and the creation of metal alloys, which would withstand tremendous temperatures and, at the same time, not lose their stability. It was also necessary to solve complex tasks in the control and computation of the rocket's trajectory. Serious problems in the field of radio technology needed to be solved.

The tremendous success, attained by radio technology, is attested by the successful solution to the problems of control of the satellites and space rockets on a planned trajectory, as well as the provision for radio communication with the earth and maintenance of it through radio technical means.

It is doubtful that the discoverer of radio, A. S. Popov, even thought about such possibilities for his discovery.

Even more so, who would have thought of similar achievements even 10-15 years ago?

Much has been created by the science of orderly theory and the hypothesis concerning the established regularity of physical phenomena which take place in the upper atmosphere of the earth and in the bowels of the universe. Science has penetrated deeply into the secrets of space. And, moreover, this branch of science has, more than any other very likely, tested the lack of definiteness in many hypotheses and has sadly needed experimental checks, but has constantly bumped up against the absence of any possibility of conducting experiments.

It was not so very long ago that scientists, mulling over the secrets of space and trying to check some one or another suppositions, did not think at all realistically about the use of artificial satellites and space rockets for this purpose, since the achievement of cosmic speeds belonged to the field of fantastic dreams.

Despite the many difficulties presented by the various direct and indirect methods much information has been obtained concerning the physical condition of the upper atmosphere.

The most complete and experimentally checked data on the study of the atmosphere has been obtained only for its lower layers. The lower layers of the atmosphere which are called troposphere, are characterized by the fact that here there is a constant agitation of the air. Up to a height of 10 km the temperature swiftly falls to 220° K (-53° C) and remains there roughly up to 25 km. Furthermore, the temperature rises to 270° K (-3° C) at a height of 60 km because of the absorption of ultraviolet rays by the ozone, which is, at the same time, a shield for living beings on earth from the destructively intensive ultraviolet ray.

One degree on the Kelvin scale (1° K) is equal to one degree on the centigrade scale (1° C). Absolute zero (-273° C) is taken as zero on the Kelvin scale.

The area lying above 30-40 km is called the upper atmosphere. Here, due to ultraviolet and X-rays from the sun and cosmic rays, the molecules of the earth's atmosphere, particularly oxygen, nitrogen, and hydrogen, are disintegrated into separate atoms (atomic oxygen, nitrogen, and hydrogen). At heights of 60-80 km the temperature falls to about 200° K (-73° C) to the so-called temperature minimum and, furthermore, rises again, reaching (according to theoretical computed data) a height of 300-400 km of its maximum 2500-3000° K.

The density of the atmosphere at a height of 15 km comprises 0.1 of the density of the earth's surface at a height of 100 km of only 0.000001, and the pressure is equal to 0.001 mm rt. st. [mercury column]. At a height of 500 km the pressure falls even millions of times. The density of the ionized interplanetary gas is estimated only by several hundreds--thousands of particles in a cubic centimeter.

Processes of active ionization take place in the upper atmosphere, producing several ionized layers, which reflect average and shortwave radio waves. Certain information concerning the atmosphere is illustrated in figure 1.

However, up until this time much remains unclarified: the distribution of temperature and density of the upper atmosphere and interplanetary gas, distribution in height of molecular and, in particular, atomic oxygen, nitrogen, hydrogen and other gases, the structure and properties of the ionosphere, the reasons for the formation and destruction of ozone, the influence of the upper atmosphere on weather conditions on the earth, etc. Experiments with the ISZ and space rockets will help to explain these and a number of other problems.

Concise information on the experiments conducted and instruments in space rockets used for this purpose are given below.

PRESSURE, DENSITY, TEMPERATURE

Pressure, density, and temperature are important characteristics of the atmosphere.

Up until now data received in experiments on the pressure, density, and temperature of the atmosphere were obtained at heights of 100-120 km. For greater heights only estimated data was obtained.

The density of the atmosphere in the ISZ and rockets was measured by ionization and magnetic electrodischarge manometers.

An ionization manometer, (Fig. 2), is a glass bulb with a system of electrodes: a grid, a collector of ions, cathode, and an additional grid. The apparatus is installed on the surface of the rocket, and works in the following way. At a definite height a cavity is revealed in the bulb of the apparatus by a special attachment. Molecules and atoms from the outer atmosphere fall into the bulb. Electrons, emitted by the incandescent cathode, bump into the molecules and atoms from the outer atmosphere and ionize them. The positive ions thus formed are attracted by the negatively charged collector.

The number of ions thus formed are proportionate to the density of the gas. The measure of gas pressure is the ion current in the collector circuit. The current in the collector current is amplified and fed to the input of the telemetering system.

The apparatus serves to measure the pressures at an interval 10^{-5} -10^{-9} mm rt. st [mercury column.].

A magnetic electrodischarge manometer (Fig. 3), whose operation principle is somewhat determined by its name, works in the following way.

Free electrons bump into molecules of gas which have fallen along with them into the bulb of the manometer, and ionize them. A discharge current, whose value is proportionate to the number of particles in a unit of volume, arises in the circuit of the anode, to which a constant voltage of 2000 volts is fed. The voltage, proportionate to the pressure with the load resistance, is fed through the amplifier to the radio telemetering system.

The manometers are equipped with special traps in order to separate the currents being measured, which is the gauge of pressure, from the currents arising from the ions and electrons, in the free atmosphere.

Data received from the rockets and ISZ indicate that the density at a height of 266 km is 10,000 times less than on the surface of the earth, and when the height is increased 100 km it decreases 10-12 times. These results agree with the results obtained on the basis of an analysis of the braking data of the satellites.

The temperature of the upper atmosphere cannot be directly measured because of the insignificant heat capacity and heat conductivity of the atmosphere, and also because of the fact that the speed of the satellite considerably exceeds the heat speeds of gas molecules. Therefore, temperature is measured according to the data for measuring pressure or density by conversions according to theoretical formulas.

COMPOSITION OF THE ATMOSPHERE

The chemical composition of the upper atmosphere is determined on the basis of an analysis of the data on the spectrum of masses of positive ions, obtained by mass-spectrometers.

A mass-spectrometer (Fig. 4) is an electrovacuum tube of a special design, containing a number of plane-parallel grids, to which corresponding voltages are fed, and a collector which gathers ions. The ions which enter the open end of the tube pass through the grids and are fed to the collector, creating a collector current. However, when the voltage in the grids is fixed and determined, only ions, which have a corresponding optimum speed depending on the mass and accelerating voltage in the grids, will reach the collector.

The accelerating voltage periodically changes in the grids of the tube from zero to a certain maximum value. In this way, the optimum speed is communicated to the ions with various numbers and their presence in the atmosphere is detected.

The ISZ showed the following regularity in the change of ion concentration.

Beginning at a height of 100 km to a height of 300 km the concentration grew ten times, and from a height of 300 km to 500 km it decreased twice.

The concentration of positive ions in the daytime at a height of 790 km was equal to 160,000 ions per cm^3, and at a height of 240 km was approximately 500,000 ions per cm^3.

It was established that atomic oxygen predominates in this field of the ionosphere. Ions of atomic nitrogen were also discovered: 3-7% of the amount of ions of oxygen. But molecular oxygen and nitrogen were not discovered.

Experiments using satellites indicated that at heights of around 1,000 km the atmosphere is extremely rarefied, but substantially less so than had been supposed.

IONIZATION OF THE UPPER ATMOSPHERE

The gases which form the atmosphere, beginning from a height of 60 km, are ionized. Ionization of the atmosphere chiefly depends on the influence of the sun.

The field of ionization, called the ionosphere, has a stratified structure and, as is well known, is characterized by four regular layers of ionization D, E, F_1 and F_2, which have the ability to reflect radiowaves and which play an essential role in their dissemination around the earth.

This field of ionization has been studied a great deal using radar technology (impulse sounding). But, all the same, the ionosphere still remains an enigma (changes in the intensity of ionization, the connection of the ionization of the atmosphere with the magnetic field of the earth etc.). There is practically no information at all about electrostatic fields and charges in the upper atmosphere (500-1,000 km). The use of radio engineering methods to investigate the upper atmosphere prevents a screening action of ionized fields.

The use of the ISZ and space rockets opens up new prospects in this field.

The voltage of electrostatic fields is measured by electrostatic fluxmeters, placed symmetrically on the surface of the satellite.

An electrostatic fluxmeter, whose diagram of principles is shown in figure 5, consists of a fixed measuring plate, connected to the frame of the satellite through the load resistance R, which is closed 1,500 times a second by means of a special screen, connected to the frame of the satellite. Since the outer electrostatic field and the field of self-discharge of the satellite accumulate at the location point of one of the data units and are read at the location point of the other data unit, the field strength of the atmosphere and the value of the self-discharge of the satellite can be computed from measurement data, given by both data units. The voltage proportionate to the charge from resistance R is fed to the amplifier and further on to the telemetering system.

Measurements, made by the ISZ and space rockets, have indicated that the field strength in the upper layers of the atmosphere is 10-100 times greater than the expected value.

Measurements on the third ISZ have also indicated that the satellite acquires a negative charge.

MAGNETIC MEASUREMENTS

The earth's magnetic field exerts a great deal of influence on a number of physical phenomena in the atmosphere. For example, such phenomena include the polarization of radio waves reflected from the ionosphere, the effect on cosmic rays, the orienting of rays of the aurora polaris, the formation of currents in the atmosphere etc.

Constant and variable components are distinguished in the earth's magnetic field. The variable part includes the regular daily variations (oscillations, changes), magnetic storms, pulsations. The source of the constant magnetic field is the internal part of the earth and only a small part, about 1%, is due to sources outside the earth. The sources for the variable components of the magnetic field are chiefly outside the earth.

The earth's magnetic field has been studied from ancient time. However, up until now much has remained unexplained. The basic thing has not been explained — the nature and origin of the earth's magnetic field. The most prevalent hypothesis is that the magnetic field of the earth is due to regular currents in its liquid conductive nucleus.

Up until now it has not been known whether there is a lunar magnetic field and what kind it is. Measurements, effected with the use of the second space rocket, have confirmed the fact that the moon does not have any perceptible magnetic field.

The study of the magnetic field in great heights and, in particular, its variable components, as well as the subsequent study of the lunar magnetic field will help the explanation of the nature and origin of the earth's magnetic field.

The magnetic measurements which have been conducted on the satellites and rockets are complicated by the effect of other apparatus on board. Magnetometers with a great measurement accuracy are used to measure the variations of the magnetic field.

The magnetometer is an instrument, a measuring data unit, which is automatically oriented along the direction of the earth's magnetic field during any orientation of the satellite (rocket). The data unit

is a permalloy plate, on which are two windings. When the plate is magnetized by the magnetic field being measured and by an auxiliary variable field due to the non-linearity of the magnetization curve of the core in the secondary winding there arises a voltage of the doubling of the frequency with an amplitude proportionate to the value of the field being measured; that is, data units are converters of signals of the constant magnetic field into an electric signal of variable voltage, a measure of the magnetic field.

COSMIC RAYS

Cosmic rays are streams of reflected particles of enormous energy, from billions to billion of billions of electron volts, passing to the earth from the depths of space. By its very nature these are atomic nuclei of light elements (about 80% hydrogen and 20% helium) and an insignificant amount of heavy nuclei. Many of their properties have been studied. However, up until now it has not been known where the cosmic rays are generated, to what their colossal energy is due, and what is their intensity in space. One hypothesis concerning the origin of cosmic rays ties their origin up with the flashes of the so-called ultra-new stars. There is a certain connection between the intensity of the cosmic ray with the large flashes on the sun, which are seldom observed (five flashes in 15 years).

The cosmic rays which have up until now been observed on the surface of the earth differ essentially from those particles which come out of space. These are chiefly secondary cosmic rays. Moreover, the trajectories of cosmic rays essentially change near the earth under the influence of the magnetic field.

The use of the ISZ and space rockets makes it possible to circumvent these difficulties and thus open up prospects for new discoveries in this field. The widely known Geiger counter is used usually to register the full intensity of the cosmic radiation. (Fig. 6). The charged particle passing through the counter creates an avalanche-like accumulating ionization of gas in the counter, which causes electric current impulses to spring up between the electrodes of the tube.

A more sensitive so-called luminescent counter is used on the ISZ and rockets, making it possible to register photons in the composition of the cosmic radiation.

A luminescent counter (Figure 7) consists of a cylindrical crystal of sodium iodine and a photomultiplier. Impulses, arising at the output of the photomultiplier, are amplified, and fed to the binary decoding network and then to the telemetering system.

The first data, received from the ISZ and space rockets, indicate that the earth is surrounded by two radiation belts (Fig. 8). The outer belt is 50,000 km away and consists of particles which have comparatively little energy. The inner belt is near the earth, 3,000-5,000 km away, and consists of particles that have a great deal of energy (30,000-100,000 electron volts). But even this energy is comparatively low. The biological defense of such particles can be assured by small protective layers of a substance.

METEORS

The study of meteoric phenomena is also of great interest, both from the point of view of astronomy and geophysics, and from the point of view of engineering.

Even at the present time the phenomenon of ionization of the atmosphere by meteors has begun to be used to organize radio communications.

At the present time it is felt that meteoric streams arise as a result of the disintegration of comets.

Up to 6,000 m of meteoric cosmic substances fall daily into the sphere of the earth. On an average, meteoric particles have a diameter of from 0.1 to 0.01 cm [centimeters]. But there are meteorites which are vast. The most massive of the preserved meteorites — the Great Greenland meteorite — weighs 37 m and its diameter is about 4 m.

The speed of meteors varies from 11 to 70 km/sek [kilometers per second].

Meteors with a mass up to 0.005 grams are observed visually. Meteors of much smaller proportions are observed by optical methods. Meteors which are still smaller can be detected by radio methods for the reflection of radio signals from meteoric ionized layers. Ballistic piezo data units are used as data units for registering meteoric particles.

A ballistic piezo data unit is a system of several piezo elements of ammonia phosphate, fastened to a plate, suspended on a flat wire. Such data units register the blows of meteoric particles up to one billionth part of a gram at a speed of 40 km/sek.

Further on the signals enter a special transformer, which ensures their division into several bands (corresponding to several bands of energy of the particles) and then into the radio telemetering system.

RADIOTELEMETERING SYSTEM

The results of scientific measurements are transmitted from the satellite to the earth in the form of radio signals with a definite form (Fig. 9) using the radiotelemetering system of ISZ (rocket) —— —earth (Fig. 10). In order to provide opportunities for a separate registration of the readings of the various instruments the ground telemetering station has a commutating device which works synchronously with the commutator on board, Synchronization is ensured by the transmission of special synchronizing impulses.

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FIGURE APPENDIX

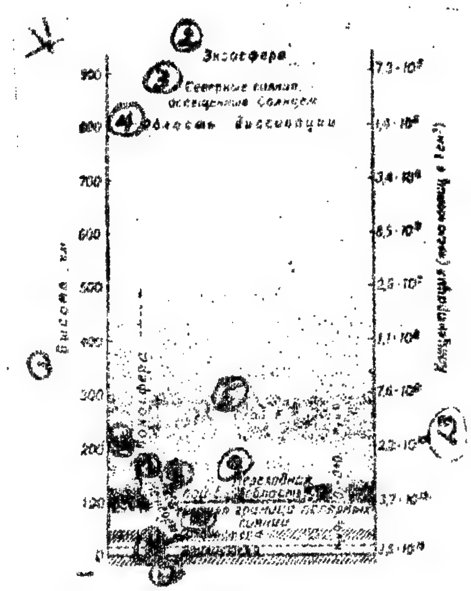

Figure 1. Certain physical properties of the earth's atmosphere

Legend:

(1) Height - km (2) exosphere (3) aurora borealis, lighted by the sun (4) area of dissipation (5) layer F (6) ionosphere (7) meteorites (8) layer E (9) transfer area (10) lower border of aurora polaris (11) ozonesphere (12) troposphere (13) concentration (number of particles per 1 cm^3)

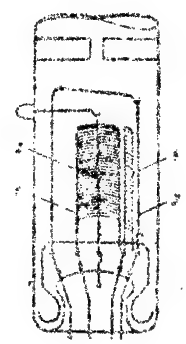

Figure 2. Diagram of the tube of the ionization manometer:

1 - grid 3 - cathode
2 - ion collector 4 - additional grid

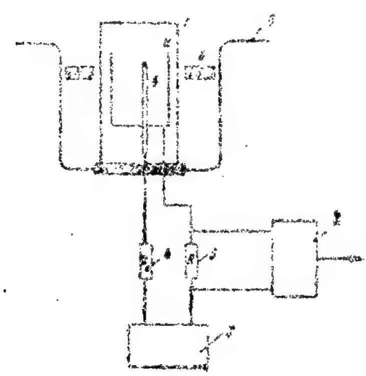

Figure 3. Diagram of the magnetic electro-discharge manometer:

1 - magnetic manometer
2 - cathode follower
3 - feed block
4 - ballast resistance
5 - resistance at the input of the cathode follower
6 - satellite shell
a - cathode.
b - anode
c - permanent magnet

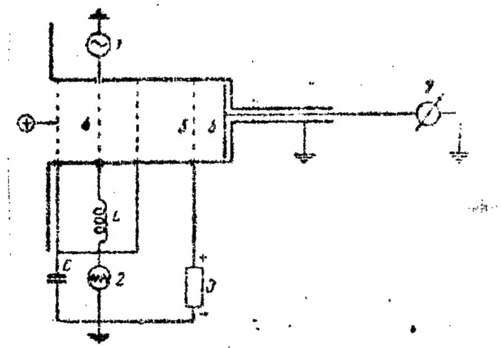

Figure 4. Diagram of the principle of the radio-frequency mass-spectrometer:

1 - source of variable voltage
2 - source of sawtooth voltage
3 - source of direct voltage
4 - triple-grid system
5 - fourth grid
6 - collector
7 - recording instrument

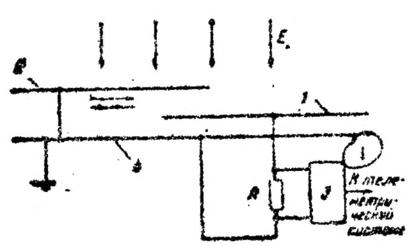

Figure 5. Diagram of the principle of the electrostatic fluxmeter:

1 - measuring sheet
2 - screen
3 - amplifier
4 - satellite shell
E - direction of lines of force of the field

Legend: (1) to telemetering system

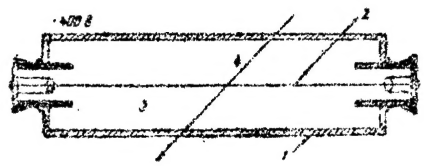

Figure 6. Diagram of Geiger counter:

1 - shell
2 - steel thread
3 - gas, which fills the counter
4 - path of particles passing through counter

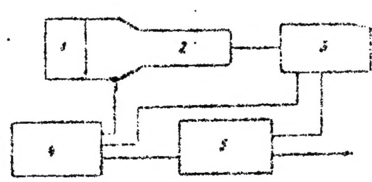

Figure 7. Diagram of luminescent counter:

1 - detector (sodium iodine crystal)
2 - photomultiplier
3 - decoding diagram
4 - feed block
5 - diagram of matching with telemetering system

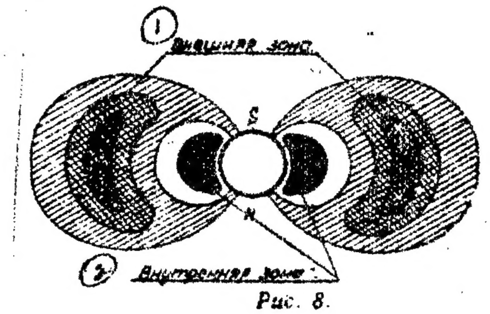

Figure 8.

Legend:
(1) "outer zone"; (2) "inner zone"

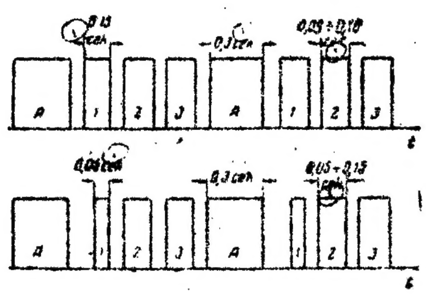

Figure 9. Form of signals of radio transmitter of telemetering system of the third ISZ (artificial earth satellite).
Above -- during operation from solar battery;
Below -- during operation from chemical sources of current;
A -- marker impulses.

Legend: (1) seconds

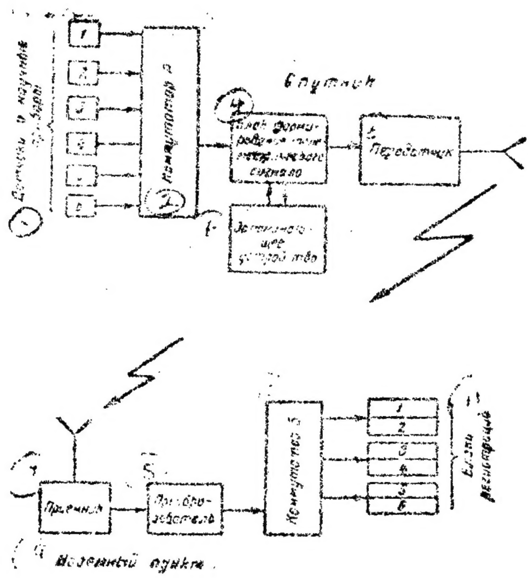

Figure 10.

Legend:

(1) Data unit and scientific instruments; (2) commutator A;
(3) satellite; (4) block for forming telemetering signal;
(5) transmitter; (6) memory device; (7) receiver; (8) converter;
(9) earth point; (10) commutator B; (11) recording blocks.

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